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Roadrunner—On the Road to Trinity

Roadrunner, the world's first petascale computer, gave weapons scientists a challenging view of the supercomputing future. For NNSA, that future will be one step closer with a machine named Trinity.

Providing the high levels of assurance needed for stockpile assessments and life extensions is a daunting task, so the supercomputers provided for weapons scientists to use tend to push computation's leading edge. Los Alamos National Laboratory's Roadrunner supercomputer won world fame for setting a computing speed record. Roadrunner has completed its life and will be decommissioned in March 2013, but NNSA continues to push computing capabilities to new, higher levels to meet Stockpile Stewardship's growing needs. So the complex is anticipating its next big computer, a machine still to be fully conceived: Trinity. Trinity will be designed and procured by a Los Alamos–Sandia partnership—the New Mexico Alliance for Computing at Extreme Scale—and physically sited at Los Alamos.

Roadrunner was a step on the road to Trinity, and it was a huge step—one for the record books.

Built for Speed

Like its namesake, New Mexico's state bird, Roadrunner was certainly speedy. In June 2008 it placed #1 on the Top500, the international list of the world's fastest supercomputers. It was the world's first petascale supercomputer, the first to reach a sustained quadrillion (thousand trillion)—1,000,000,000,000,000—calculations, or floating-point operations, a second: petaflops.

Roadrunner also had a unique, and controversial, design (architecture) for a supercomputer. It combined two different kinds of processors, making it a "hybrid." It had 6,563 dual-core general-purpose processors (AMD Opterons), with each core linked to a special graphics processor (PowerXCell 8i) called a "Cell." The Cell was an enhanced version of a specialized processor originally designed for the Sony Playstation 3, adapted specifically to support scientific computing.

Although hybrid computers had existed before, no one had ever tried that approach at supercomputing scale, and many doubted that a hybrid supercomputer would work. So for Los Alamos and IBM, collaborators in designing and building the computer, Roadrunner was a leap of faith—but a leap with purpose.

High-speed calculation was part of the purpose. Although simulation only *predicts* weapon performance, when nuclear testing *demonstrated* it, simulation pays a two-part dividend: greater detail about the internal processes feeding into performance and increased fidelity in spatial and temporal resolution. When a computer is fast enough to improve detail and fidelity, with reasonable turnaround time, the resulting simulations deepen scientists' understanding of weapon behavior. As part of its Stockpile Stewardship work, Roadrunner took on a troubling, long-standing gap in understanding about energy flow in a weapon and its relation to yield and made a significant contribution to that understanding. But the need to improve detail and fidelity for full scale weapons calculations continues to drive the need for even faster, and bigger computers.

A Shot across the Bow

Another significant purpose behind Roadrunner was the need to free the weapons codes from their dependence on computer architectures that are rapidly becoming antiquated.

The current NNSA computing workhorse is a supercomputer named Cielo. Cielo is more like previous Stockpile Stewardship workhorses (not a hybrid) while operating at Roadrunner scale: 1.3 petaflops. It was built to accommodate the present-day weapons codes, and its continuity with previous systems gives all the codes time to be prepared for future machines. But Cielo will be the last of its kind.

Computer technology is changing very quickly. Companies are trying new architectures and developing new technologies, such as different kinds of processors, memory units, and interconnects, and the national laboratories' supercomputers must follow those commercial trends. Such innovations constitute an entirely new software environment, so the next generation of supercomputers will be radically different from the supercomputers of the last twenty years.

Roadrunner's speed was derived from its architecture. Its two processors shared functions, with the Cell taking on the most computationally intense parts of a calculation and so acting as a computational accelerator. But the division of tasks was not automatic. Developers had to revise their preexisting codes, puzzling out how best to divide calculations between the processors and how to distribute data so that it would be in the right place when needed. As code developers grappled with such problems, they were hearing a warning shot that alerted them to upcoming changes in high-performance computing. What Roadrunner did was exactly what it was intended to do: get the weapons codes moving toward new architectures. Roadrunner was challenging because the supercomputing future is challenging.

Forward to Trinity
Sometime between 2020 and 2030 supercomputers will reach exascale—one quintillion (1,000,000,000,000,000,000) calculations per second—one thousand times faster than Roadrunner. Such speed bodes well for the needs of the weapons labs --- if it can be used.

Roadrunner made great strides in energy efficiency by linking its general-purpose processors to specialized ones. “Roadrunner wasn’t the first time anyone had thought of using specialized processors that way,” says Gary Grider, who heads Los Alamos’ High Performance Computing Division. “But Roadrunner was the first really big demonstration of what that means. So we produced a petaflop machine using 3 megawatts of power. The Jaguar supercomputer at Oak Ridge used 8 megawatts of power to get petaflop speed because they were doing things the old-fashioned way—using only general-purpose processors.”

Future supercomputers will need to improve on Roadrunner’s energy efficiency to make the power bill affordable. Future supercomputers will also need new solutions for handling and storing the vast amounts of data involved in such massive calculations. And they will need to achieve greater resiliency—the ability to extend the time between system failures. Supercomputers’ continuously increasing size makes resiliency a serious issue.

Improving efficiency and resiliency, along with reaching exascale, is happening in stages, and Trinity, tentatively projected for installation at Los Alamos in 2015–2016, will be the next stage of the journey for the NNSA’s ASC program.

Trinity’s exact design is still under discussion. Trinity will be an Advanced Technology System—a new ASC category replacing both “Advanced Architecture” and “Capability.” It could be 40 to 50 times faster than Roadrunner and Cielo. Like Roadrunner, it will break significantly with the past, and like Cielo, it will serve as the working platform for *all* the Stockpile Stewardship codes that must be run at large scales. As such, Trinity is expected to be the first platform large enough and fast enough to begin to routinely accommodate finely resolved 3D calculations for full-scale, end-to-end weapon calculations; in fact, such calculations provided the design basis for Trinity.

The Smart Supercomputing Future
Roadrunner got everyone thinking in new ways about how to build and use a supercomputer. Specialized processors are being included in new ways on new

systems, and being used in new ways. “So our demonstration with Roadrunner,” says Grider, “caused everyone to pay attention.”

Certainly Trinity’s designers are paying attention. They have a lot of new ideas on the table and so will be making a lot of decisions before the machine becomes a reality. The final picture is still out of focus. But if the exact nature of Trinity remains uncertain, what *is* certain is that it will not do what Cielo does—provide a comfortable environment for current, unadapted weapons codes. So the code developers at Los Alamos and all the weapons labs are already changing their codes to fit tomorrow’s radical architectures.

Trinity is on the way, with exascale and who knows what else right behind. Roadrunner’s warning advises everyone to get ready.

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